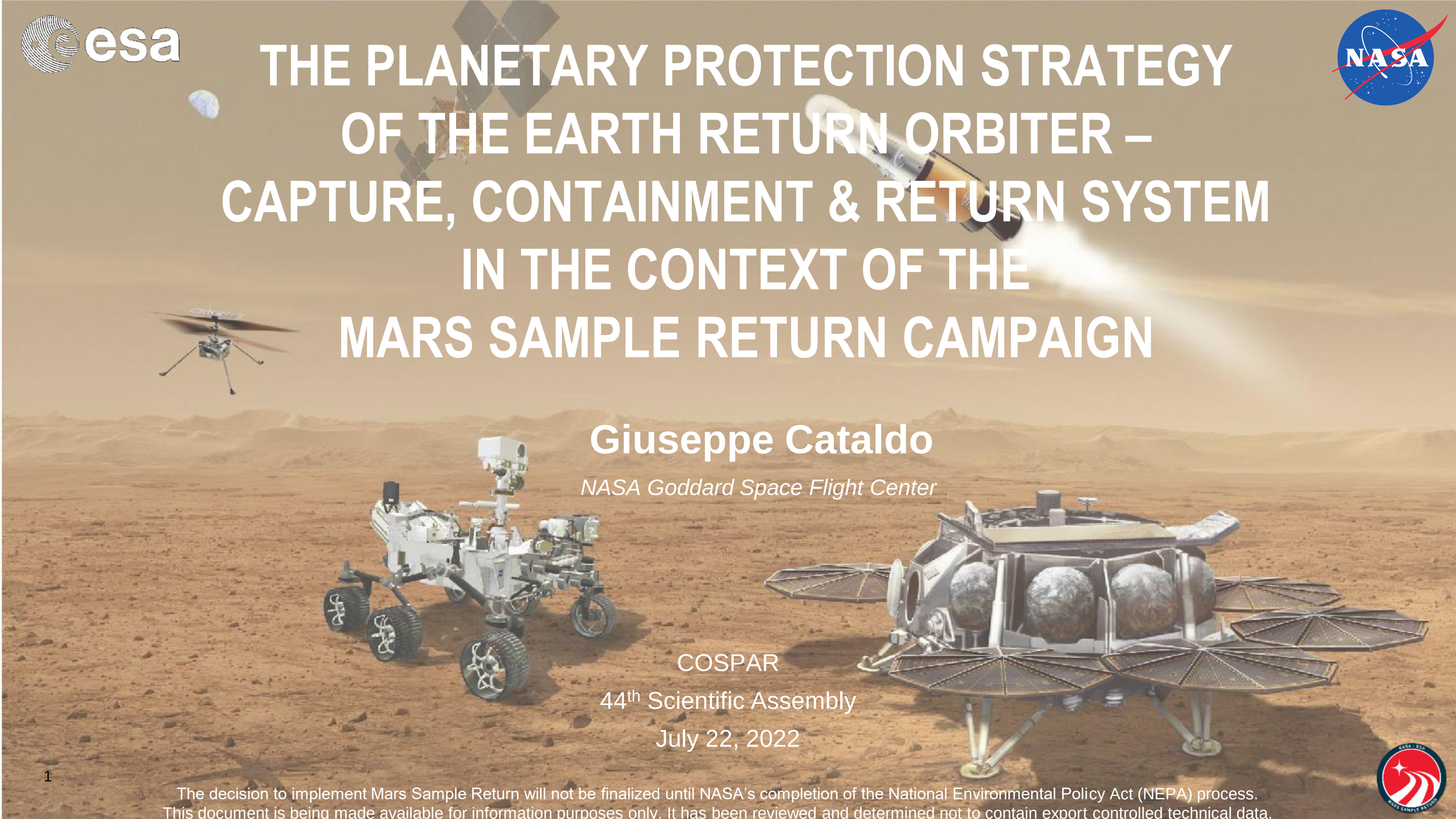

THE PLANETARY PROTECTION STRATEGY OF THE EARTH RETURN ORBITER – CAPTURE, CONTAINMENT & RETURN SYSTEM IN THE CONTEXT OF THE MARS SAMPLE RETURN CAMPAIGN

Giuseppe Cataldo

NASA Goddard Space Flight Center

COSPAR

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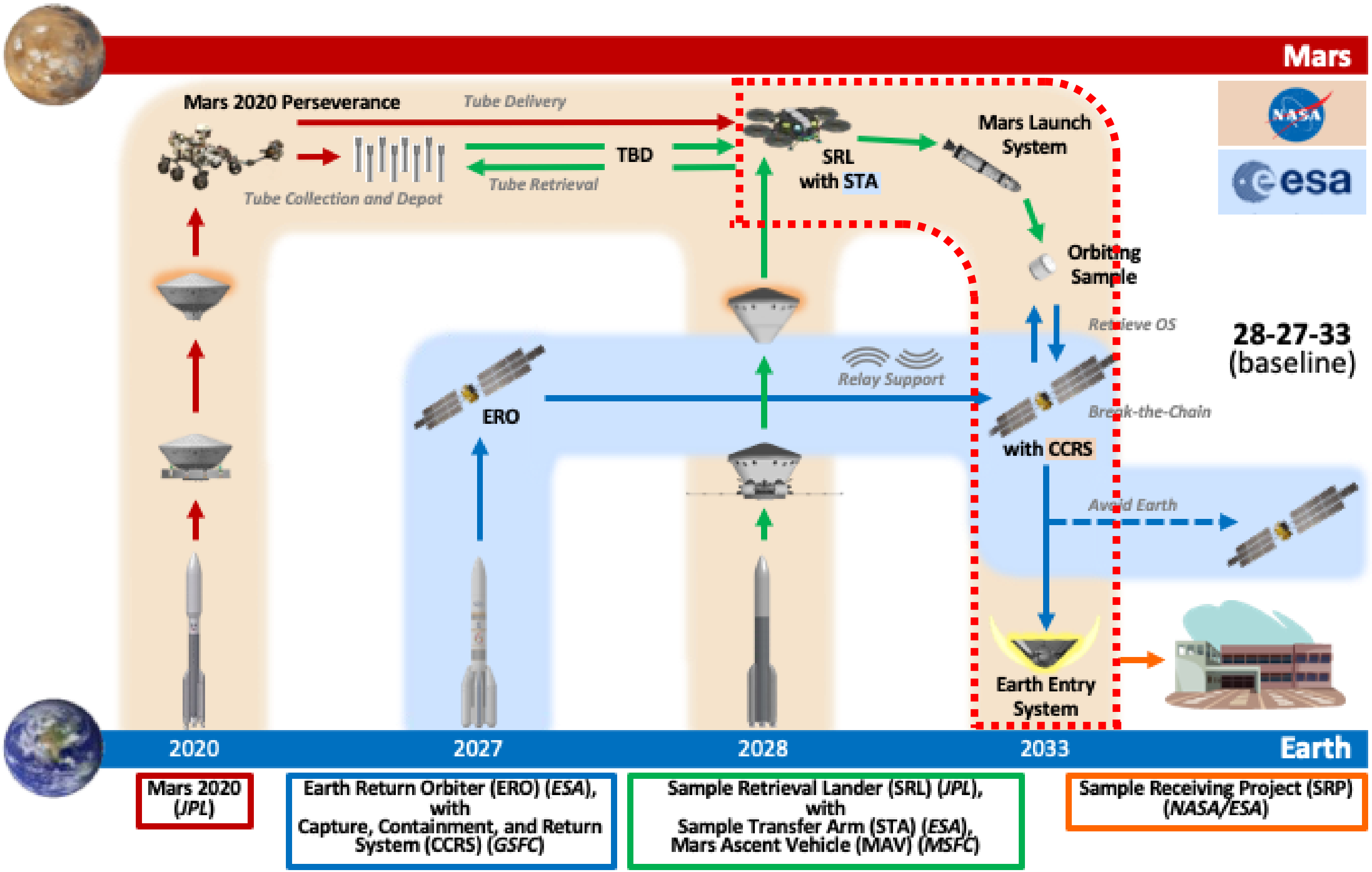
Outline

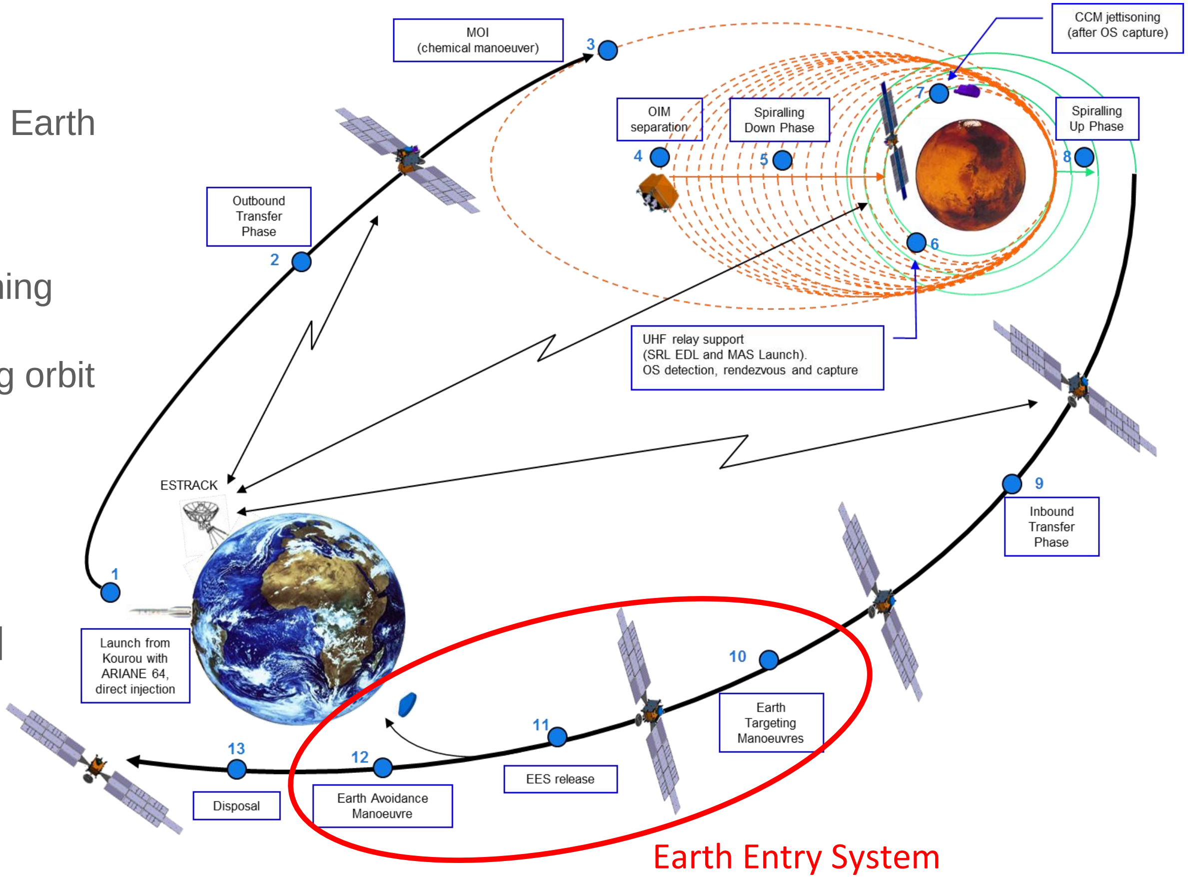
- MSR campaign overview
- ERO mission overview
- CCRS payload overview
- Mission planetary protection categorization
- Implementation of backward planetary protection policies
  - Particle control
  - Sterilization
  - Redundant containment
- Conclusions

Planned MSR Campaign Architecture Overview



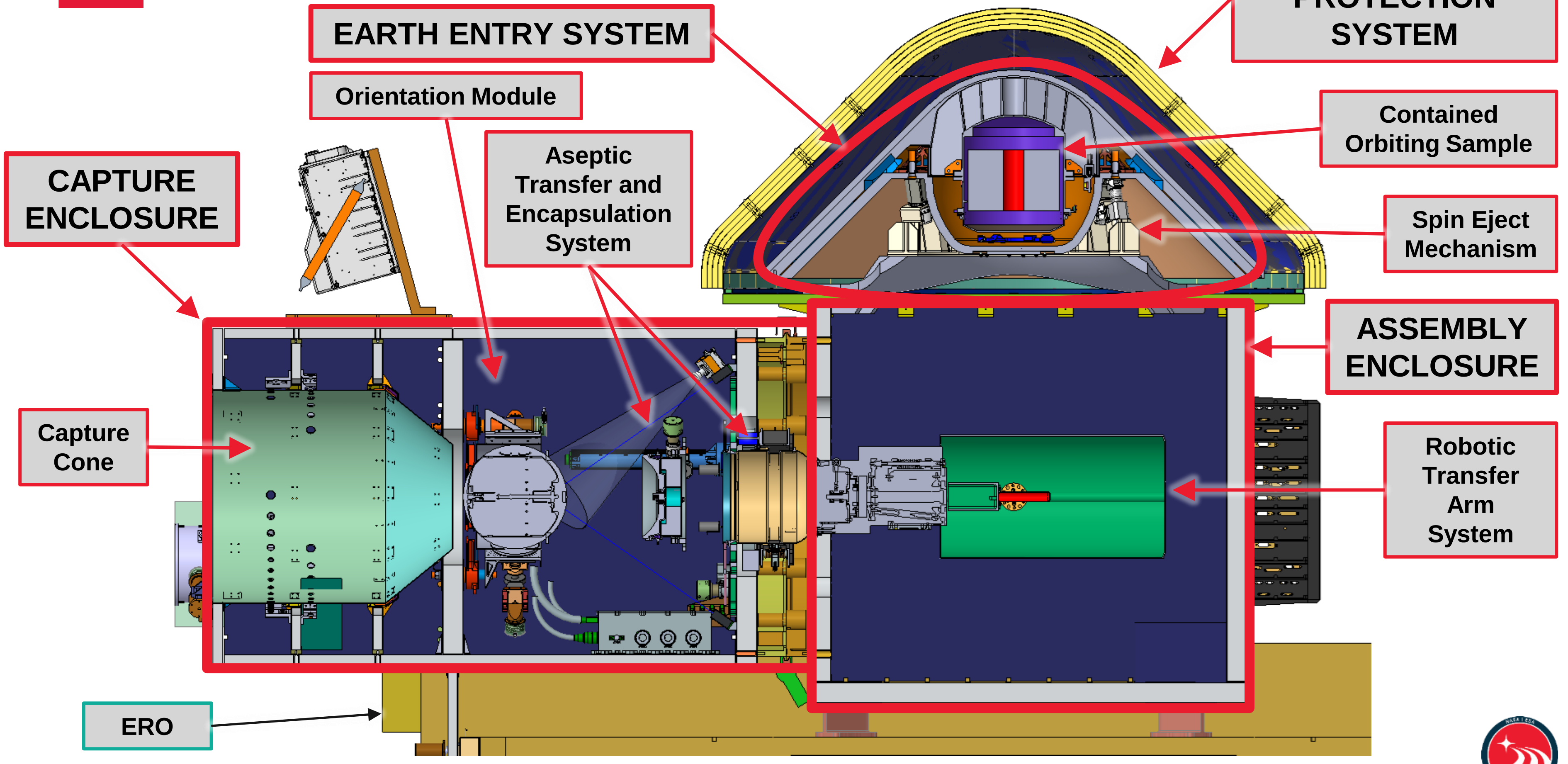
ERO-CCRS mission overview

- Mission objectives:
  - Capture the OS and bring it back to Earth
  - Relay support for Mars assets
- Nominal mission ("28/27/33"):
  - Launch and near-Earth commissioning [30 days]
  - Outbound transfer with helio parking orbit [3 years]
  - Mars orbit insertion [2 weeks]
  - Spiral down [<1 year]
  - Low Mars orbit (relay support, OS rendezvous, OS containment) [1-1.5 years]
  - Spiral up [<1 year]
  - Inbound transfer [1 year]
  - EES delivery phase [few days]
  - Retirement [few days]



Key document is "CReMA": ERO Consolidated Report on Mission Analysis, Rev 2.0 (Apr 2022)

CCRS payload overview



ERO Planetary Protection Categorization

FPP Cat.	BPP Cat.	Element	Target Bioburden Cleanliness*	Execution
III	V(r)	CCRS Capture Enclosure	N/A	Separates from ERO for disposal in either a Mars or heliocentric orbit.
		CCRS Earth Entry System	N/A	Sterilization and containment to break the chain of contact, anomaly detection, robust and redundant containment through entry, descent and landing.
		CCRS Assembly Enclosure CCRS Micrometeoroid Protection System	N/A	Disposed with ERO in a heliocentric orbit that avoids Earth for at least 100 years.

- Per NASA-ESA MOU, CCRS will comply with NASA FPP requirements at delivery to ESA for integration and perform to NASA BPP standards as an element of the MSR Program during flight.

* ERO plans orbits to be stable for longer than the required impact avoidance period or be limited in duration such that the probability of spacecraft failure during execution remains below impact probability requirements (<1% impact probability for the first 20 years after launch, <5% impact probability for the 30 years thereafter) consistent with COSPAR PP guidelines.

  – ERO requirements include compatibility with bioburden assessments to ensure a bioburden-based compliance path is possible if mission success considerations result in Mars orbital parameters that exceed allowable Cat. III impact probabilities.

Break the chain of contact between Mars and Earth

Active, surface-to-surface (Mars-to-Earth) process to satisfy BPP goals by prohibiting uncontrolled transmission and release of **extraterrestrial material of concern** into Earth's biosphere.

– BPP is about defining and achieving the appropriate risk posture, BTC is an implementation-focused part of it, mandated by NASA HQ.

BREAK THE CHAIN

PARTICLE TRANSPORT (“Leave behind”)
Adhesion
Transmission
Emission

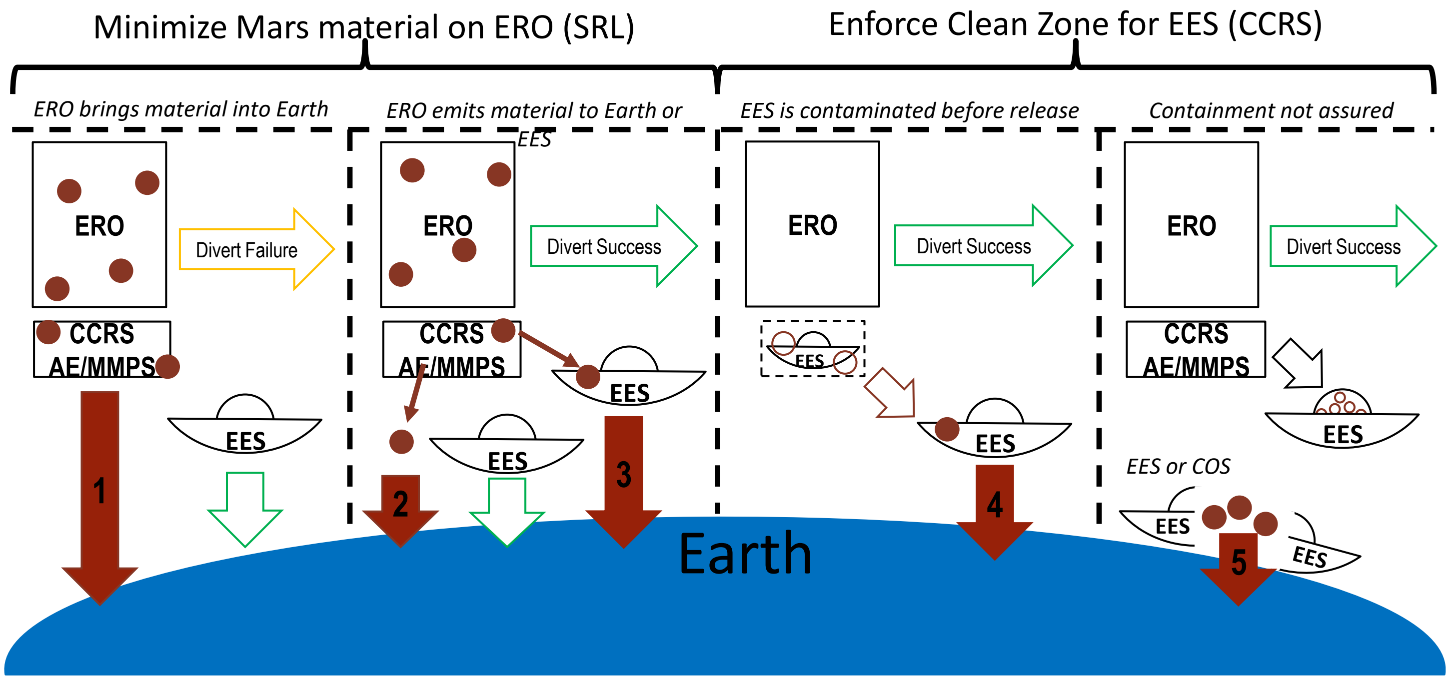
STERILIZATION (“Kill”)
Inactivation
(natural or engineered)

CONTAINMENT (“Lock up”)
Sealing
Encapsulation
Isolation
Blocking

ASEPTIC TRANSFER
Move something from a dirty volume to a clean volume without transmitting Mars material

Particle Control

- There are 5 primary paths (of Mars material) that can enter Earth's biosphere
- Paths can be controlled by minimizing material on specific surfaces
- End-to-end, physics-based, analytical framework developed to track particles on hardware

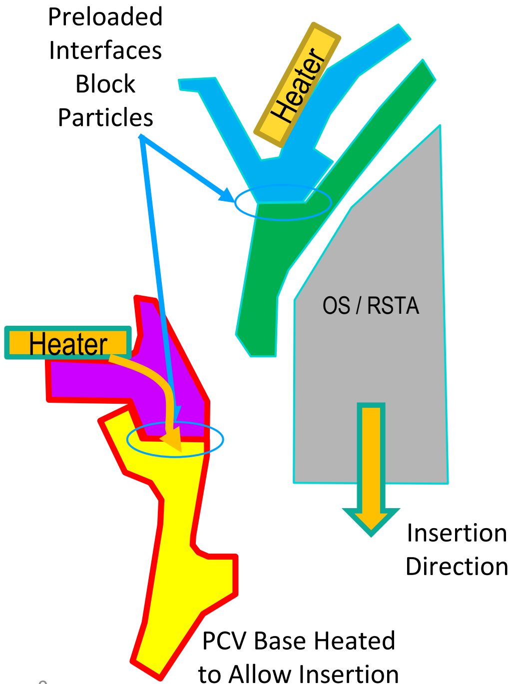


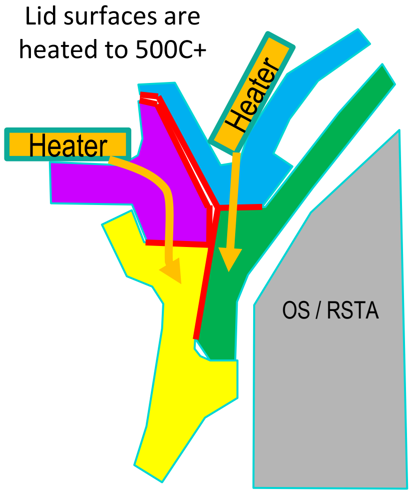
Sterilization

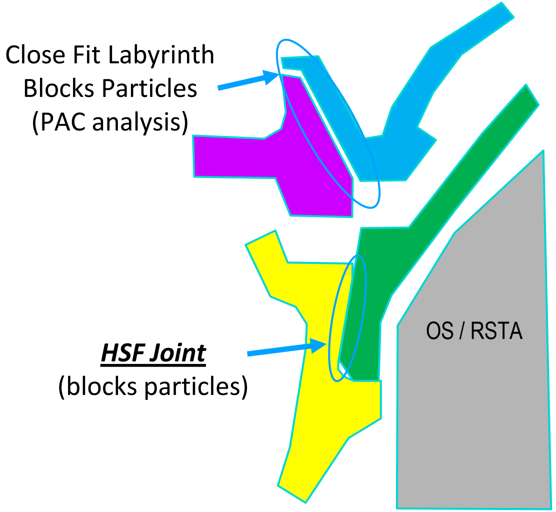
Potential biohazards from Mars

- **Bacterial endospores** as the bounding case for heat-resistance in whole organisms
- **Yeast prions** as the bounding case for resilient proteins that can proliferate catalytically

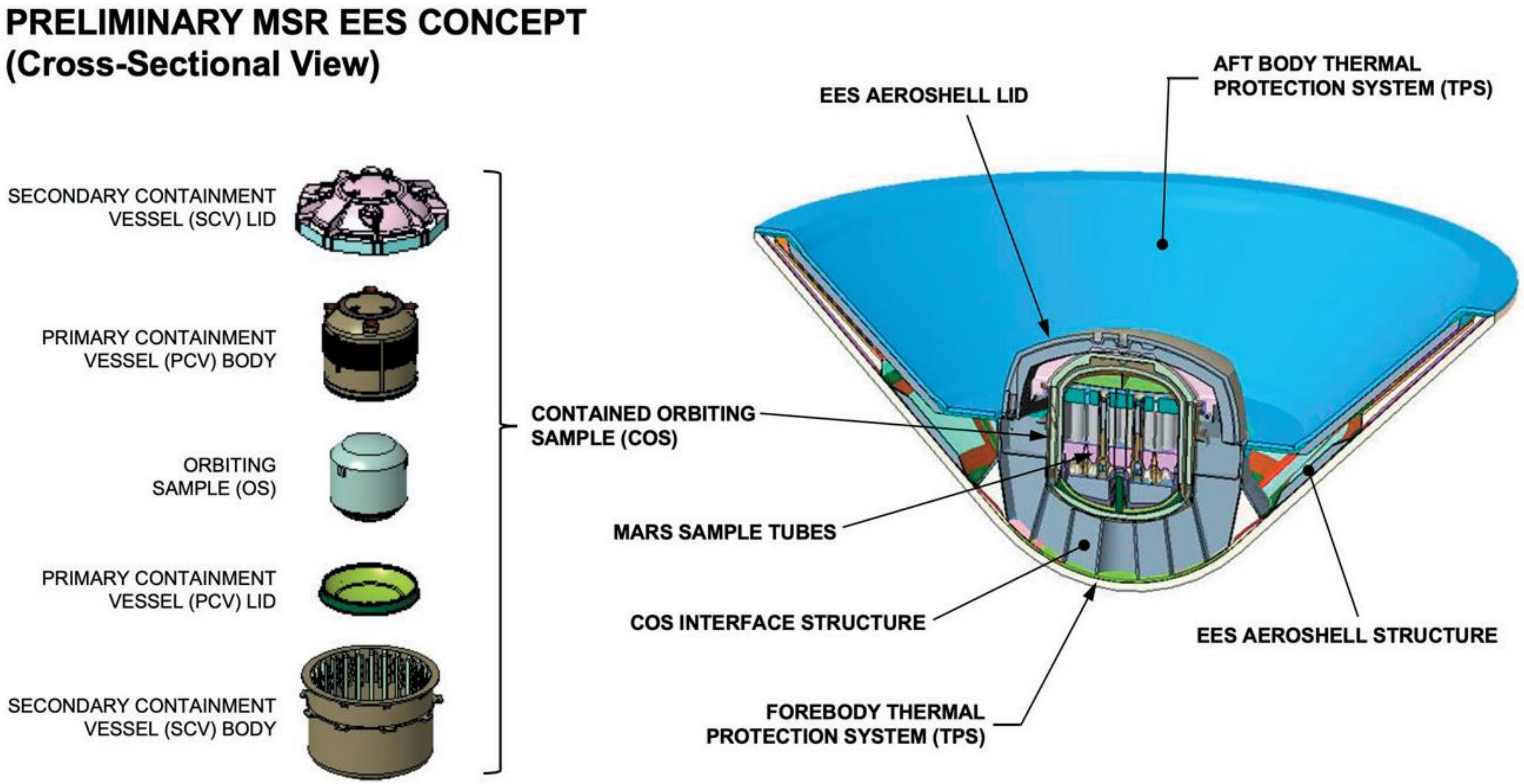
- Prior to the heated shrink fit operation, preloaded joints (blue-green and purple-yellow) prevent particles from migrating from Mars dirty to Earth clean regions
- The heated shrink fit joint has an interference fit at temperatures near ambient, but a clearance fit when the outer component (yellow) is heated to high temperatures (> 500°)
  - At temperature, the two can easily be inserted into one another, but upon cooling they form a difficult to separate joint
  - This joint is compressively preloaded across its entire surface, blocking particles from escaping the PCV during robotic assembly and EDL
- The heated shrink fit insertion occurs above 500C+, thereby also sterilizing the surfaces.



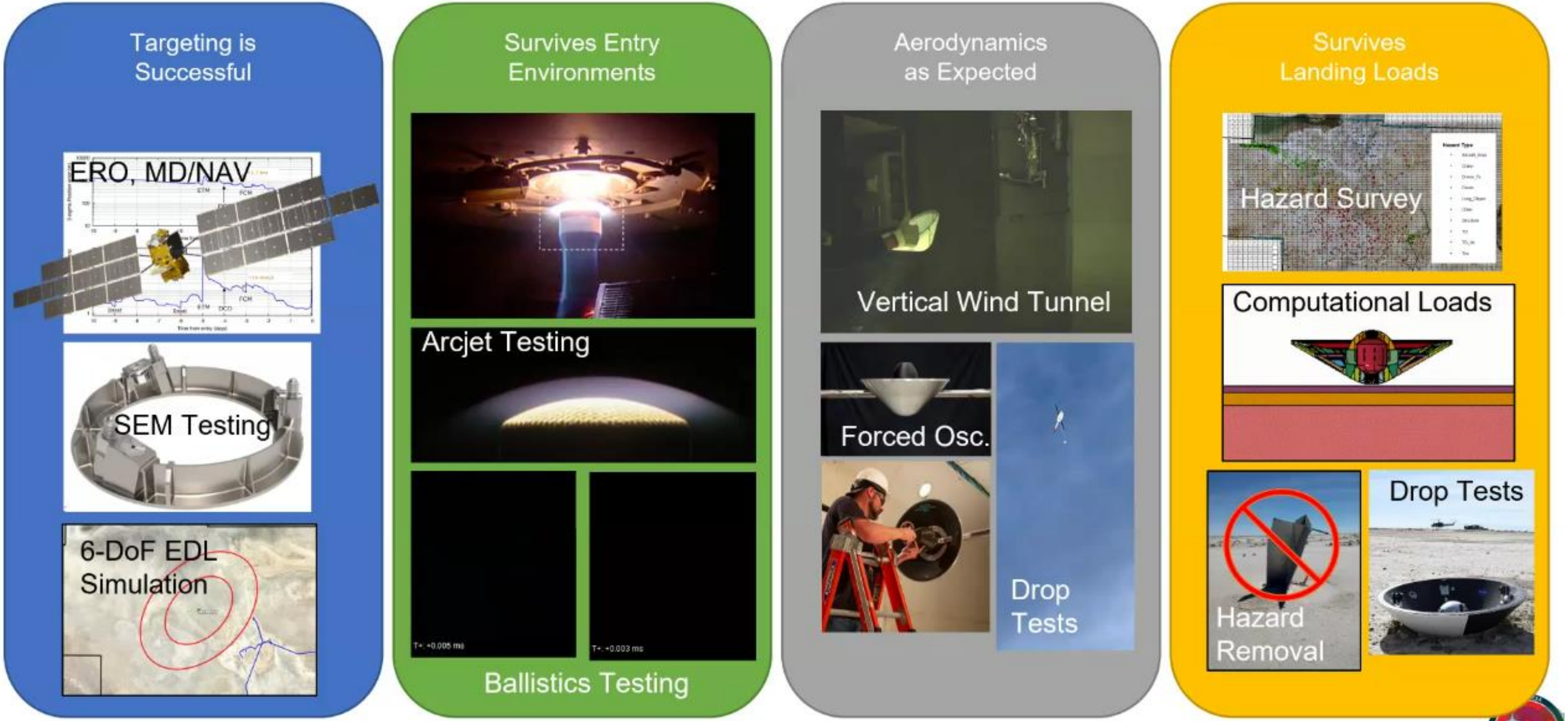




Containment Assurance



Containment Assurance during Approach, Entry, Descent, Landing



Conclusions

Robust protective measures are being designed to protect Earth's biosphere

- Assessing the risk
  - Sampling location and conditions present an **extremely low likelihood** of presence of hazardous biological material.
- Safety first
  - Securely **contain** all **unsterilized** Mars material returned to Earth.
- Break the chain
  - Containment engineering and verification activities that sequentially reduce the potential that any unsterilized Mars material could be released into Earth's biosphere.
  - Many of these protective measures provide layers of **redundancy** throughout the mission and would enable safe sample return under a variety of mission conditions.
- Orbital trajectory
  - The EES would be **pointed away** from Earth until a few days before the planned landing, allowing a final decision to be made about proceeding with Earth entry using all available information collected during the entire mission.
- Materials to tolerate extreme conditions (high velocities and forces)
  - The EES would enter the Earth's atmosphere at nearly 27,000 mph, experience forces nearly 125 times greater than gravity while slowing to just 90 mph, and land using only the ground as its cushion.
  - The cone-shaped vehicle and its components are being **robustly designed and tested** on Earth to demonstrate their ability to withstand forces well beyond those that would be experienced during entry and landing.
- Care upon landing - Treat as if they could be hazardous biological materials
  - The EES will be quickly enclosed in **additional layers** of containment, using procedures based upon the proven principles and techniques used by hazardous material response teams, and will be maintained through transport to a dedicated Mars sample receiving facility.
  - Such a Mars sample receiving facility would have design and sample handling requirements equivalent to those of biological safety laboratories used for research studies of infectious diseases.

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– Scott Perino	JPL	CCRS Containment Assurance Lead
– Radford Perry	NASA GSFC	CCRS Forward PP Lead, Particle Control Lead

- The BPP/BTC team

– Kyle Grello	NASA GSFC	CCRS Reliability Engineering Lead
– Christine Szalai	JPL	CCRS Approach, Entry, Descent & Landing Phase Lead
– Peter Gage	NASA ARC	CCRS Earth Entry System (EES) Systems Engineer
– Bruno Sarli	NASA GSFC	CCRS EES Protection & Release Phase Lead
– Many others		

- The entire CCRS team

- Any questions? Reach out at Giuseppe.Cataldo@nasa.gov

@GCataldoNASA